



AGRONOMIC AND ECONOMIC ANALYSES OF  
SOYBEAN-WHEAT CROPPING SYSTEMS

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## INTRODUCTION

The two chapters of this thesis are separate and complete manuscripts to be submitted to the Agronomy Journal for publication. The format of each conforms to the style of that journal.

and response to a

## CHAPTER I

### Economic Analysis of Soybean-Wheat Cropping Systems

## Economic Analysis of Soybean-Wheat Cropping Systems<sup>1</sup>

### ABSTRACT

Soybeans [*Glycine max.* (L.) Merr.] are well suited for multi-crop systems. Soybeans are adapted to a wide range of soil types and through nitrogen fixation, soybeans can efficiently "fix" most of their own nitrogen. This makes soybeans a good rotational crop with high nitrogen-consuming crops. Numerous studies have been conducted on cropping systems that incorporate soybeans and wheat [*Triticum aestivum* (L.)] (Crabtree et. al., 1990). Research has evaluated tillage, planting methods, row spacing and cultivar selection. The objective of this study was to determine the economic consequences of six soybean-wheat cropping systems. These systems included monocrop soybeans in 25 and 76 cm rows (MC-25 and MC-76), doublecrop soybeans-wheat in 25 and 76 cm rows (DC-25 and DC-76), and a 3-crop/ 2-year pattern with soybeans in 25 and 76 cm rows (3/2-25 and 3/2-76). The 3-crop/ 2-year pattern produces two single purpose and one dual-purpose crop in a two-year period: an early season soybean crop, a full season soybean crop, a wheat forage crop, and a wheat grain crop. An economic analysis of the six systems was conducted to compare net returns to land, labor, and management. The study was arranged in a randomized complete block design with a two row spacing by three cropping pattern factorial. The study was at the Vegetable Research Station, Bixby, OK and the Eastern Research Station, Haskell, OK. The study was conducted during three periods: Period 1= 1992-93, Period 2= 1994-95, and Period 3= 1996-97. The 3-crop/ 2-year pattern required a two-year period to complete one cycle. The 3/2-25 system produced the greatest net return in each period at Bixby (\$760, \$756, and \$602/ ha in Periods 1, 2, and 3, respectively) and the greatest net

return at Haskell in Period 1 (\$1049/ ha). Over the six-year period and over both locations of this study, the 3/2-25 system produced the greatest average net return per period of \$765/ ha. The 3/2-76 system produced the second highest average net return of \$685/ ha. This system produced \$580/ ha/ period net return at Bixby and \$790/ ha/ period net return at Haskell. The MC-76 produced an average overall net return of \$566/ ha. The DC-25 produced an average of \$562/ ha and the DC-76 produced an average of \$558/ ha in net return. The lowest overall average net return was produced by the MC-25 system with an average net return of \$528/ ha.

Additional Index Words: soybeans, *Glycine max.* (L.) Merr, wheat, *Triticum aestivum* (L.), cropping system, doublecrop, row spacing, economic analysis.

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<sup>1</sup>To be submitted for publication in the Agronomy Journal.

## Introduction

Today farmers realize that they must get the maximum usage from their farmland because of an ever-growing world population, changes occurring in U. S. farm policies, and the growing cost of inputs. The farmer must implement economically feasible cropping systems to survive. Soybeans [*Glycine max.* (L.) Merr.] are well suited for most multi-crop systems. They have the ability to perform well under a wide range of soil types and soybeans can efficiently “fix” most of their own nitrogen if sufficient numbers of *Rhizobium* sp. bacteria are applied at planting or are present in the soil (Varvel and Peterson, 1992). Nitrogen fixation reduces production costs and makes soybeans a good rotational crop for use with high nitrogen-consuming crops. Soybeans are sometimes doublecropped with wheat because of wheat’s flexibility. Wheat can be used as a forage crop, a dual-purpose forage and grain crop, or a grain crop alone.

Much of the agronomic research has been conducted on tillage and planting methods (Touchton and Johnson, 1982), water use efficiency (Daniels and Scott, 1991), row spacings (Cooper, 1977; Alessi and Power, 1982) and crop rotations (Crabtree et. al., 1990; Sanford et. al., 1973). Information on economic evaluations of production systems is lacking. Economic analyses were used to evaluate the profitability of different herbicide practices (Paudel et al., 1998), row spacings (Oriade et al., 1997), and the use of doublecropping verses relay intercropping (Moomaw and Powell, 1990). Studies in Kansas compared a wheat-sorghum-fallow rotation to a wheat-corn-fallow rotation while using different tillage practices (Norwood and Currie, 1998). Studies in Mississippi evaluated the net returns above specified costs from cropping systems adapted to the Tunica clay soils of the lower Mississippi River floodplain (Wesley et. al., 1995).

Traditional soybean cropping patterns include monocrop soybeans, doublecrop soybeans-wheat and soybeans-corn (or other summer crop) rotations. The 3-crop/ 2-year cropping pattern is unique. It involves early season soybeans planted in April and harvested in August or September; wheat planted in September, forage harvested during winter, and seed harvested in June; full season soybeans planted in June and harvested in November; and a fallow period from November through March. Each cycle requires a two-year period to complete. This pattern may solve some of the agronomic problems inherent in the monocrop and doublecrop patterns. The 3-crop/ 2-year pattern produces four crops (two single purpose soybean crops and a dual-purpose wheat crop) during a two-year cycle; whereas, only two crops are grown with the monocrop pattern. One of the advantages of the 3-crop/ 2-year pattern over the doublecrop pattern is that the 3-crop/ 2-year pattern provides a wheat forage crop during alternate years. The wheat crop in the traditional doublecrop pattern is planted too late for forage production. More time for required tillage also differentiates the 3-crop/ 2-year pattern from the doublecrop pattern. Doublecropping soybeans and wheat does not usually allow time to perform conventional tillage practices. The 3-crop/ 2-year pattern provides a period for different types of tillage to be preformed. For example, the 3-crop/ 2-year pattern allows more time to perform deep tillage to break up a hard pan. Also, with doublecropping the normal harvest time of one crop coincides with the preferred planting time of the alternate crop. The 3-crop/ 2-year pattern permits more time for key operations, which is a good risk management tool. Part of this versatility comes from the use of early maturing soybeans. The use of these early planted, early maturing soybeans in the cropping pattern helps spread out harvest time and increases the number of options available for subsequent

crops (Kane and Grabau, 1992). Also, early season soybeans may take advantage of spring rainfalls and avoid droughts that occur in late summer. From an economic standpoint, early maturing soybeans help spread machinery and labor costs over more days and allow producers to spread fixed costs over more acres (Casey et. al., 1998). In addition, soybean prices are usually higher in early Fall when early season soybeans are harvested.

The objective of this study was to determine the economic consequences of six alternative soybean-wheat cropping systems. The cropping patterns included monocrop soybeans, doublecrop soybeans-wheat, and 3-crop/ 2-year soybeans-wheat pattern with soybean row spacings of 25 and 76 cm in all three patterns. Economic analyses evaluated the net returns to land, labor, and management for each system.

## Materials and Methods

The experimental design for this study was a randomized complete block with four replications. The six treatments were arranged in a two row spacing by three cropping pattern factorial. The 76 cm rows represent traditional row spacing and the 25 cm rows represent drill planting. The three cropping patterns were monocrop soybeans (MC), doublecrop soybeans-wheat (DC), and a 3-crop/ 2-year (3/2) pattern involving soybeans and wheat. The six cropping systems were designated MC-25, MC-76, DC-25, DC-76, 3/2-25, and 3/2-76. The experiment was conducted over a six-year period at two locations: the Vegetable Research Station at Bixby, OK and the Eastern Research Station at Haskell, OK. The plots at the Bixby location were 36.6 m by 19.8 m and the plots at the Haskell location were 19.8 m by 8.8 m. A 10.7 m alley was not planted between each replication and a 4.0 m border was planted on each side of the test. A 3.1 m by 19.8 m section was harvested from each plot for grain yield. The weight of seed harvested was recorded and converted to kilograms per hectare.

Two soybean cultivars were used in the study. A Group III soybean variety (9391) was selected as the early season soybean cultivar. Choska, a Group VI cultivar, was selected as the full season soybean cultivar (Edwards et al., 1995). During years one through three of this study, the wheat variety Karl was used (Sears et al., 1991). During years four through six, the wheat variety 2163 was used because Karl began to exhibit leaf rust susceptibility in 1994.

Each cropping system was managed according to accepted agronomic practices for the area. The monocrop soybean systems (Table 1) included moldboard plowing the fields in March. The fields were disked in late April or early May and again in June.



Preplant herbicides were applied and incorporated into the soil. Full season soybeans were planted in mid-June. The fields were cultivated in mid-July as needed and sprayed with post-emergence herbicides to control weeds. The monocrop soybeans were harvested in late October or early November. The land was fallowed until time to moldboard plow again for the next season's planting.

The doublecrop soybeans-wheat systems are also presented in Table 1. A wheat grain crop was harvested in late June of year one. Herbicides were sprayed over the wheat stubble immediately after harvest. Full season soybeans were planted no-till. Herbicides were used during the summer as needed. These soybeans were harvested in November, as they became mature. The fields were double disked and planted to wheat as soon as possible, thereafter.

For the 3-crop/ 2-year (Table 2) systems, the fields were moldboard plowed in February of year one. The fields were disked in late March and preplant herbicides were applied for weed control and incorporated into the soil. Early season soybeans were planted between April 1-10. The soybeans were cultivated and herbicides were applied as needed throughout the growing season. These soybeans were harvested in early September. The fields were double disked immediately and planted to wheat. Wheat forage was produced from November 1 through March 1 of the next year. Wheat grain crops were harvested in June. The fields were sprayed for weed control and full season soybeans were planted, no-till, in late June. Herbicides were used as needed during the summer. Soybeans were harvested at maturity in November and the land fallowed for over four months. The land was moldboard plowed in December, January, or February.

Economic analyses were conducted by partial budget procedures. Interest, management, labor, land and taxes were not figured into the analyses. Economic values were based on current rates for all inputs and outputs. All inputs and outputs were on a per hectare basis so that values across all systems from all years could be compared to one another. The study was broken down into three periods of two years each corresponding with each cycle of the 3-crop/ 2-year pattern (Period 1 = 1992-93, Period 2 = 1994-95, and Period 3 = 1996-97). In one period the monocrop soybean pattern produced two soybean crops and the doublecrop soybeans-wheat pattern produced two soybean crops and two wheat crops. The 3-crop/ 2-year system produced two soybean crops (an early season soybean crop and a full season soybean crop), a wheat forage crop, and a wheat grain crop. The Oklahoma Farm and Ranch Custom Rates, 1994-95 report distributed by the Oklahoma Cooperative Extension Service was used to determine the cost of tillage, planting, cultivation, harvesting, hauling, and spraying (Jobes and Kletke, 1994). Estes Chemical Co., Muskogee, OK, provided herbicide costs. Fertilizer costs were obtained from Muskogee Farmers Association, Muskogee, OK, and prices for soybeans and wheat seed were provided by Oklahoma Foundation Seed Inc., Stillwater, OK and Ron Limon, Coweta, OK. Market values for the wheat and soybean grain were obtained from the Wall Street Journal. The wheat price used for all analyses was \$.10/ kg quoted on Monday, June 15, 1998. The soybean price used was \$.19/ kg quoted on Tuesday, September 15, 1998. Wheat forage was valued at \$23.26/ ha / year (Doye and Kletke, 1997). Gross returns were determined for each cropping system using these market values and measured yield data. Fixed costs in this study included planting, harvesting, tillage, and hauling cost. Variable costs included seed, fertilizer, and

herbicide costs. Net return represents the excess of gross return over total specified costs (fixed and variable) on a per hectare basis (Oriade et al., 1997) and reflects the return to land, labor, and management. An analysis of variance (ANOVA) test was conducted using the net return values for each period at each location and all periods combined at each location. An average total cost was developed for both locations. Least significant differences (LSDs) were also determined at the .05 level.

## Results and Discussion

This study determined the economic implications of the combination of alternative cropping patterns and different row spacings. Partial Budgets were developed for each of the six cropping systems to determine the net return to land, labor, and management for each cropping system.

Table 3 presents the net returns for each cropping system for the three periods at the Bixby location and the average of the three periods. In Period 1, the 3/2-25 system produced significantly greater returns (LSD @ .05= \$101) than each of the other five treatments. It produced a net return of \$760/ ha. There was no significant difference observed between the MC-25 system with a net return of \$631/ ha and the 3/2-76 system with a net return of \$615/ ha. There was a significant difference between the net return of the 3/2-76 system and the MC-76 system (\$484/ ha). The two doublecrop systems showed no significant difference between them and each had a significantly lower net return than the MC-76 system. The LSD value for Period 2 was \$142. No significant difference was observed between the net returns of the 3/2-25 and the MC-25 systems. The 3/2-25 system again had the highest net return with \$756/ ha, which was significantly higher than the 3/2-76, DC-25, DC-76, and MC-76 systems. The MC-25 and 3/2-76 systems produced \$678 and \$604/ ha, respectively. There were no significant differences observed between the net returns of the MC-25 and the 3/2-76 systems or between the MC-25 and the DC-25 systems. The fourth highest return came from the DC-25 system at \$562/ ha. No significant difference was observed between the 3/2-76, DC-25, DC-76, or the MC-76 systems. Also, a difference could not be observed between the DC-25 system and the DC-76 system or between the DC-25 system and the MC-76

system. Nor could a difference be observed between the DC-76 and the MC-76 systems. The final period shows an LSD of \$84. There was no significance difference between the top net return (3/2-25, \$602/ ha) and the second highest net return (3/2-76, \$521/ ha). The 3/2-25 system did produce a significantly higher return than each of the other systems. No differences were observed between the net returns of the 3/2-76, the MC-25, and the MC-76 systems. There was a significant difference observed between the MC-76 system and the DC-76 system. No difference was observed between the DC-76 and the DC-25 systems. The doublecrop systems produced the lowest returns. The 3-crop/ 2-year pattern out-performed the other cropping patterns. Although the monocrop and doublecrop patterns fluctuated as to which one was the second most efficient pattern, the doublecrop pattern normally was the lowest in net returns. This could be partially attributed to the high fixed and variable costs. Pooled data for the three periods at Bixby produced an LSD of \$61. The 3/2-25 system was significantly higher than each of the other systems with a net return of \$706/ ha / period. There was no difference observed between the net returns for the MC-25 and the 3/2-76 systems, which produced \$594 and \$580/ ha / period, respectively. The 3/2-76 system produced significantly higher returns than each of the remaining systems. A difference in net returns was also observed between the MC-76 and DC-25 systems. The MC-76 system produced \$482/ ha / period and the DC-25 system produced \$409/ ha / period. The DC-76 system produced the lowest net return of \$396/ ha/ period, but it was not significantly less than the DC-25 system. Part of the reason the doublecrop systems were usually in the lower half of the returns could be attributed to the higher variable cost. Bixby normally had a high weed population and more herbicides were needed to help control weed outbreaks. Both the

DC-25 and DC-76 averaged over \$660/ ha / period in total cost, \$662 and \$662/ ha/ period respectively. The weeds were not such of a problem at Haskell.

Haskell data are presented in Table 4. In Period 1, no significant difference (LSD @ .05= \$72) was observed between the top net return produced by the 3/2-25 system (\$1049/ ha) and the 3/2-76 system (\$1016/ ha). There was a significant difference between the 3/2-76 and each of the other systems. A significant difference was observed between the MC-76 and the DC-76 systems. No significant difference was observed between the DC-76 and the DC-25 systems. There was a significant difference between the DC-25 and the lowest net return of the MC-25 system. The MC-25 system only produced a net return of \$306/ ha. In Period 2 an LSD value of \$72 was obtained. This period produced totally different results compared to the other periods at Haskell or Bixby. No significant differences were observed between the DC-76, the DC-25, or the MC-25 systems. The DC-76 system had the highest net return at \$801/ ha and its counterpart the DC-25 system produced the second highest net return at \$750/ ha. This was a complete roll reversal compared to the other periods where the two doublecrop systems were normally towards the middle or bottom. There was also no significant differences observed between the DC-25, the MC-25, the 3/2-25, or the MC-76 systems. Also, no differences were observed between the third through the fifth returning systems or the fourth through the fifth returning system. No significant difference was observed between the MC-76 and the lowest net return (3/2-76 system, \$619/ ha). The LSD for Period 3 was \$94. No significant differences were observed between the top return (3/2-76), the second return (3/2-25), or the third return (DC-25). Also there was no difference between the second (3/2-25) and third (DC-25) systems. The highest net return came

from the 3/2-76 system with a net return of \$736/ ha. No significant difference was observed between the DC-25 and the DC-76 systems, but the DC-76 system was significantly higher than the MC-76 system. No difference was observed between the MC-76 system and the lowest producing system, the MC-25 system. With the exception of Period 2 the cropping patterns preformed much like they did at Bixby. The 3-crop/ 2-year pattern out-preformed the other two patterns. At Haskell however, the doublecrop pattern normally preformed better than the monocrop pattern. At Haskell, all three periods were also pooled. With an LSD of \$42 the highest net return came from the 3/2-25 system with a return of \$823/ ha/ period. However, no significant difference was observed between the 3/2-25 system and the second highest system the 3/2-76 system (\$790/ ha/ period). There was a significant difference between the 3/2-76 system and the DC-76 system, but no difference between the DC-76 and DC-25 systems. The DC-76 system had a net return of \$719/ ha/ period and its counterpart the DC-25 system had a net return of \$714/ ha/ period. Significant differences were observed between the fourth (DC-25) and fifth (MC-76) and between the MC-76 system and the lowest producing system (MC-25). The pooled data of the three periods shows that at Bixby (Table 3) the monocrop pattern out-preformed the doublecrop pattern and that at Haskell (Table 4) the two patterns switched. Part of this could be attributed to the higher weed concentration at Bixby as compared to Haskell, which would cause higher variable cost.

Further confirmation of how the 3-crop/ 2-year pattern out-performed the alternatives is evident when data from all three periods and both locations were pooled. Table 5 presents the average net returns for both locations combined over the six years this study was conducted. An LSD of \$66 was found. The 3/2-25 system produced the

highest average net return of \$765/ ha and was significantly different than each of the other systems. The 3/2-76 system produced a net return of \$684.79/ ha. A significant difference was observed between the 3/2-76 and the MC-76 systems. The MC-76, DC-25, DC-76, and MC-25 systems had no significant differences between them. A significant difference could not be observed between the DC-25, DC-76, and MC-25 systems or the DC-76 and MC-25 systems. The MC-25 system produced the lowest average net return at \$528/ ha. The results of the combined data once again punctuate the fact that the 3-crop/ 2-year pattern out-performed the monocrop and doublecrop patterns. Although the 3-crop/ 2-year pattern had total costs that normally were between the total costs of the other two patterns, the 3-crop/ 2-year pattern's gross returns were always the highest. Also by looking at this data you can see that the 25 cm soybean rows out-performed the 76 cm rows. The 25 cm rows averaged \$618/ ha while the 76 cm rows only averaged \$603/ ha.



## Conclusion

The results from this study provide support for the 3-crop/ 2-year pattern compared to the other two cropping patterns. The 3/2-25 system produced the highest net return in all three periods at Bixby (\$760, \$756, and \$602/ ha, respectively). At Haskell the 3/2-25 system produced the highest net return in Period 1 (\$1049/ ha), fourth highest in Period 2 (\$692/ ha), and second highest in Period 3 (\$728/ ha). Overall the 3/2-25 system produced the highest average net return over both locations over the six years with an average net return of \$765/ ha. The next highest net returning system was the 3/2-76 system. At Bixby the 3/2-76 system produced the third highest net return in Period 1 and 2 (\$615 and \$604/ ha, respectively) and the second highest return at \$521/ ha in Period 3. With the exception of Period 2 at Haskell, where it produced the lowest net return, the 3/2-76 system was always close to the top in net returns. The 3/2-76 system produced the second highest net return in Period 1 (\$1016/ ha) and the highest net return of \$736/ ha in Period 3.

A difference was found between the two locations with the other two cropping patterns. At Bixby, the monocrop soybean pattern was consistently the second most productive pattern followed by the doublecrop soybean-wheat pattern. At Haskell however, the doublecrop soybean-wheat pattern produced the better net returns. It was the second most productive pattern in Periods 1 and 3 and it was the highest producing pattern in Period 2. When both locations were averaged together, there were no significant differences between the monocrop soybean pattern and the doublecrop soybeans-wheat patterns.

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Table 5. Average cost and returns for Bixby and Haskell, OK combined: 1992-1997

TABLE 1  
MONTHLY ACTIVITIES FOR THE MONOCROP AND  
DOUBLECROP SYSTEMS

	Monocrop	Doublecrop
January		
February		Topdress wheat with nitrogen. <sup>†</sup>
March	Moldboard plow.	
April	Disk in the later part of the month.	
May	Disk if needed.	
June	Disk around the middle of the month. Apply preplant herbicides, incorporate, and plant soybeans.	Harvest wheat and spray for weed control and plant soybeans, no-till.
July	Cultivate soybeans or use herbicides for weed control.	Control weeds with herbicides.
August	Control the weeds by spot spraying if necessary.	Control weeds with herbicides.
September		
October	Harvest soybeans in later part of month.	
November		Harvest soybeans and double disk land after harvest. Plant winter wheat. Fertilizer applied.
December	Fallow until time to moldboard plow for next year.	

<sup>†</sup> Wheat was established in November of the previous year.

TABLE 2  
MONTHLY ACTIVITIES FOR THE 3-CROP/ 2-YEAR SYSTEMS

	Year 1	Year 2
January	Moldboard plow as early as possible (Dec., Jan., or Feb.)	
February		Topdress wheat with nitrogen.
March	Double disk in the later part of the month.	
April	Apply preplant herbicides, incorporate and plant early season soybeans as early as possible.	
May	Cultivate and use herbicides, if necessary.	
June	Cultivate and use chemical weed control, if necessary.	Harvest wheat grain; spray wheat stubble for weed control, and plant (no-till) full season soybeans.
July	Control the weeds by spot spraying.	Use chemical weed control, if necessary.
August		Use chemical weed control, if necessary.
September	Harvest soybeans, double disk the land, and plant wheat. Fertilizer applied.	
October		
November	Wheat forage produced from November 1 through March 1.	Harvest soybeans at maturity. Fallow period.
December		Moldboard plow the land or other tillage as early as possible (Dec., Jan., or Feb.).

TABLE 3

NET RETURNS FROM SIX CROPPING SYSTEMS INVOLVING  
SOYBEANS AND WHEAT AT BIXBY, OK: 1992-1997

Management Systems	Period 1 1992-93	Period 2 1994-95	Period 3 1996-97	Average of 3 Periods
	Net Returns <sup>†</sup> , \$/ ha			
MC-25	631	678	473	594
MC-76	484	490	472	482
DC-25	364	562	299	409
DC-76	369	509	311	396
3/2-25	760	756	602	706
3/2-76	615	604	521	580
LSD @ .05	101	142	84	61

<sup>†</sup> Net returns to Land, Labor, and Management.



TABLE 4

NET RETURNS FROM SIX CROPPING SYSTEMS INVOLVING  
SOYBEANS AND WHEAT AT HASKELL, OK: 1992-1997

Management Systems	Period 1 1992-93	Period 2 1994-95	Period 3 1996-97	Average of 3 Periods
	Net Returns <sup>†</sup> , \$/ ha			
MC-25	306	738	344	463
MC-76	840	683	428	650
DC-25	720	750	672	714
DC-76	753	801	605	719
3/2-25	1049	692	728	823
3/2-76	1016	619	736	790
LSD @ .05	72	72	94	42

<sup>†</sup> Net returns to Land, Labor, and Management.

TABLE 5  
AVERAGE COST AND RETURNS FOR BIXBY AND  
HASKELL, OK COMBINED: 1992-1997

Management Systems	Gross returns	Variable cost	Fixed cost \$/ ha	Total cost	Net returns <sup>†</sup>
MC-25	850	127	195	322	528
MC-76	889	128	195	323	566
DC-25	1205	221	423	644	562
DC-76	1201	220	423	643	558
3/2-25	1244	165	315	480	765
3/2-76	1163	163	315	478	685
LSD @ .05					66

<sup>†</sup> Net returns to Land, Labor, and Management

CHAPTER II  
Agronomic Analysis of Soybean-Wheat  
Cropping Systems

## Agronomic Analysis of Soybean-Wheat Cropping Systems<sup>1</sup>

### ABSTRACT

Because farmland is becoming scarcer and the world's population continues to expand at a geometric rate, farmers must realize maximum usage from their land. The most productive method to realize this is to implement a cropping system that is highly suitable for the location of the farm and that will produce the greatest crop yields on the available acreage. Soybeans [*Glycine max.* (L.) Merr.] have been shown to be well suited for most multi-crop systems. Many studies have been conducted on cropping systems that incorporate soybeans and wheat [*Triticum aestivum* (L.)]. One of the advantages of using wheat in cropping systems is its flexibility. Wheat can be used as a forage crop, a dual-purpose forage and grain crop, or grain crop alone. The objective of this study is to evaluate yields produced from six different soybean-wheat cropping systems. The systems include monocrop soybeans at 25 and 76-cm rows (MC-25 and MC-76), doublecrop soybeans-wheat at 25 and 76-cm rows (DC-25 and DC-76), and 3-crop/ 2-year pattern at row spacings of 25 and 76-cm rows (3/2-25 and 3/2-76). The 3-crop/ 2-year pattern is unique because in a two-year period two single purpose and one dual purpose crops can be produced: an early season soybean crop, a dual purpose wheat for forage and grain crop and a full season soybean crop. These systems were evaluated on an agronomic level to determine yield differences across systems. The study was arranged in a randomized complete block with a two row spacing by three cropping pattern factorial at two locations: the Vegetable Research Station, Bixby, OK. and the Eastern Research Station, Haskell, OK. The study was conducted during three periods: Period 1= 1992-93, Period 2= 1994-95, and Period 3= 1996-97. The 3-crop/ 2-year

pattern requires a two-year period to complete one cycle. The yield results from this study provide support for the use of the 3-crop/ 2-year pattern over the other two cropping patterns with the 3/2-25 system being the most productive for soybeans. In soybean yields, the 3/2-25 system was the highest producing system two of the three periods at Bixby (Period 1= 5192 kg/ha and Period 2= 6123 kg/ha). In Period 3 it was the fourth highest producing system (3793 kg/ha). At Haskell it was again the highest producing soybean system in two of the three periods (Period 1= 6668 kg/ha and Period 3= 5094 kg/ha) and it was the second highest producing system in Period 2 with 5588 kg/ha produced. Overall the 3/2-25 system produced 5410 kg/ha of soybeans and 1893 kg/ha of wheat. The next most consistent producing system was the 3/2-76 system. In the three periods it was in the top two or three in soybean production at both Bixby and Haskell. Even though it was one of the lowest wheat producing systems, the 3/2-76 is still the second best system in this study.

Additional Index Words: soybeans, *Glycine max.* (L.) Merr, wheat, *Triticum aestivum* (L.), cropping system, row spacing, doublecropping, monocropping.

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## Introduction

As today's farmland becomes scarcer and the world's population continues to expand at a geometric rate, farmers must obtain the maximum usage from their land. They need a cropping system that is suitable for the location of the farm and that will produce the greatest crop yields on the available acreage.

Soybeans [*Glycine max.* (L.) Merr.] are well suited for most multi-crop systems. They have the ability to adapt to a wide range of soil types. Soybeans can efficiently "fix" most of their own nitrogen through a symbiotic relationship with *Rhizobium* sp. bacteria, who convert atmospheric N to a metabolizable ammonium nitrate. An advantage of nitrogen fixation is a reduction in production cost. It also makes soybeans a good rotational crop for use with high nitrogen-consuming crops such as corn. They have also shown promise as a crop that may reduce the leaching of nitrate-N into the ground water (Varel and Peterson, 1992).

Soybeans are one of the major oil-producing crops in the world. They play a role in the manufacturing of many industrial products and are widely used in cooking oils. They are used to produce milk substitutes for children who are allergic to casein, flour to improve texture and shelf life of bakery goods, and even as meat substitutes or meat extenders. Soybeans have a high protein content of between 30 – 40 percent (Yadrick, 1973). Because of this high protein content the by-products of oil extraction are suitable for use as a feed supplement for livestock. A processed bushel of soybeans (60-lbs.) can yield 47 pounds of meal and 11 pounds of oil, with the meal containing around 45 percent protein (Sholar, 1997). Soybean production has increased significantly over the past several years. In 1980-81 over 49 million hectares of soybeans were produced

worldwide. Over 80 million tons of soybeans are produced annually. The United States, Brazil, China, and Argentina account for 90 to 95 percent of world production (Smith and Huyser, 1987).

One of the problems that occurs in a rain fed cropping system is having adequate soil moisture for seed germination and stand establishment. In wheat producing regions with adequate frost-free days to permit doublecropping, water is often the most limiting factor in producing a second crop. Soil moisture present at the time of wheat harvest is the critical factor for determining the potential yield of the following soybean crop. If soil is quite dry at the time of wheat harvest, doublecropping should not be attempted. If the subsoil has been depleted of moisture by the wheat crop, soybean growth will depend on rain falling during July and August. Most failures can be avoided by not planting when the soil is dry at the time of wheat harvest. As the old saying goes "If June is dry. Do not try" (Jeffers, 1995). Several studies have been conducted to determine how tillage or row spacing affect the content of soil water when doublecropping soybeans and wheat. Studies have also been conducted on water use efficiency and how management practices affect this water use efficiency when dealing with doublecrop soybeans (Crabtree and Rupp, 1980; Daniels and Scott, 1991).

One of the reasons wheat is used extensively in cropping systems is because of its flexibility. Wheat can either be used as a forage only crop, a dual-purpose forage and grain crop, or as a grain only crop. The wheat forage may be grazed full season, harvested for hay or silage, or grazed during the vegetative growth stages (Krenzer, 1986). Many things must be managed properly to make grazing wheat a success. Things

like variety, fertilization, and the timing of the grazing are all factors that must be watched.

Nearly one-third of the total soybean acreage in the Southeast is doublecropped with wheat (Carlson and Marra, 1986). Farmers use doublecropping because they are highly leveraged and need to achieve higher income and risk diversification (Shapiro et. al., 1992). Some of the widely accepted potential advantages of doublecropping are: (i) better utilization of climate, land, and other resources; (ii) reduction of soil and water losses because the soil is covered during most of the growing season with a plant canopy; and (iii) enhanced utilization of soil-, water-, and energy-conserving tillage methods (Caviness and Collins, 1985). Doublecrop systems such as wheat following soybeans are efficient in much of the Eastern United States, from Georgia to Southern Illinois and west to Oklahoma. In this system, no-till soybeans are the most common practice. After wheat harvest, soybean yield potential decreases each day that planting is delayed. To reduce time between wheat harvest and soybean planting, time-consuming tillage practices are often eliminated and soybeans are grown with minimum or no-tillage production practices. However not much is known about how this lack of tillage effects the yield of doublecrop wheat. In 1982 a study was conducted on the effects of soybean tillage and planting methods on the yield of doublecrop wheat and soybeans (Touchton and Johnson, 1982). Three types of tillages were used: no-till, chisel, and moldboard plow on two types of soil, Appling (Typic Hapludult) and Cedarbluff (Fragiaquic Paleudult). Also three different types of planting techniques were used: drilled (18-cm rows), in-row subsoiling (69-cm rows), and conventional without subsoiling (61-cm rows). In the three environments tested, the no-till soybean production without in-row



subsoiling reduced wheat grain yield an average of 509 kg/ha when compared to chiseling and moldboard plowing. Generally, planting soybeans with in-row subsoiler eliminated adverse effects of no-till soybean production on wheat yields in the Georgia study. Soybean yields were approximately equal for the chisel and plow treatments but wheat yields were often lower on the chiseled than on the plowed soil. These results suggest that plowing or at least chiseling prior to planting soybeans will result in higher yields of doublecrop wheat than no-till soybeans unless the soybeans are planted with in-row subsoiler.

No tillage in a doublecrop system requires a high level of management and continuous supervision to anticipate unusual problems and to perform each operation at the most appropriate time. The most critical part of a doublecrop system is planting time. Planting time is critical if the normal maturity date of the preceding crop extends into the normal planting range of the succeeding crop. No-till planting provides the least delay in establishing a second crop, thereby increasing the chances for success in doublecropping. A study was conducted to determine which cropping system, doublecrop soybeans-wheat or grain sorghum-wheat, was most adaptable and profitable on a Blackbelt soil (Sanford et al., 1973). Another objective was to determine if soybeans and grain sorghum crops could be grown successfully by planting them directly into wheat stubble. The study showed that wheat grown after soybeans yielded significantly more than wheat grown after grain sorghum. The difference was attributed primarily to the beneficial effects of residual nitrogen from the previous crop of soybeans. Soybeans and grain sorghum no-tillage practice produced 25.4 and 48.3-bu/acre respectively. However, the conventional tillage produced a higher yield for both the soybeans (33.4-bu/acre) and grain sorghum

(57.5-bu/acre) on a two year average. Sanford et. al., 1973 also found that the wheat-soybean cropping system produced significantly higher net returns over specified production cost than the wheat-grain sorghum system.

Crabtree et. al., 1990 conducted a 12-year study to look at the long-term effects of wheat, soybeans, and grain sorghum doublecropping under rainfed conditions. Over the 12-yr period monocrop wheat averaged 3050 compared with 2510 and 2450 kg/ ha when doublecropped with soybean and grain sorghum, respectively. Conventionally tilled monocrop soybean and grain sorghum and no-till doublecropping of both soybean and grain sorghum after wheat produced grain 11 out of 12 years. The monocrop soybeans averaged 2470 compared with 1930 kg/ha for no-till doublecrop soybeans. Monocrop grain sorghum averaged 5130 compared with 4200-kg/ha for doublecrop grain sorghum. During the years of average rainfall amounts and distribution, yields of doublecrop soybean and grain sorghum were competitive with those of monocrop soybean and grain sorghum. These results indicate that yields of doublecrop wheat, soybean, and grain sorghum can be sustained over long periods of time.

Traditional soybean cropping pattern include monocrop soybeans, doublecrop soybeans-wheat and soybeans-corn (or other summer crop) rotations. The 3-crop/ 2-year cropping pattern is unique. It involves early season soybeans planted in April and harvested in August or September; wheat planted in September, a forage crop harvested from November through February, and grain harvested in June; full season soybeans planted in June and harvested in November; and a fallow period from November through March. Each cycle requires a two-year period to complete. This pattern may solve some of the problems inherent in the monocrop and doublecrop patterns. Monocropping

soybeans year after year is a very inefficient way to manage most cropland. With the 3-crop/ 2-year pattern, two soybean crops and one dual purpose wheat crop are grown during a two year cycle; whereas, only two crops are grown with the monocrop pattern. More time for required tillage differentiates the 3-crop/ 2-year pattern from the doublecrop pattern. Doublecropping soybeans and wheat does not usually allow time to perform needed tillage practices. The 3-crop/ 2-year pattern also gives the farmer the chance to use their wheat crop as a forage crop. This is something the doublecrop pattern does not allow. The 3-crop/ 2-year pattern provides a period for tillage. Also, with doublecropping the normal harvest time of one crop coincides with the preferred planting time of the alternate crop. The 3-crop/ 2-year pattern provides more versatility, which is a good risk management tool. Part of this versatility comes from the use of early maturing soybeans. The use of these early planted, early maturing soybeans in the cropping system helps stagger out harvest time and increases the number of options available for subsequent crops (Kane and Grabau, 1992). Plus, they take advantage of the spring rainfalls, which help them avoid the droughts that occur in late summer. From an economic standpoint, early maturing soybeans help spread machinery and labor costs over more days and allow producers to spread fixed costs over more acres (Casey et. al., 1998). Normally soybean prices are better in the early part of fall, which coincides with the harvest of early season soybeans.

The objective of this study was to evaluate the yield potential of six different soybean-wheat cropping systems. The systems used were monocrop soybeans (25 and 76 cm row spacing), doublecrop soybeans-wheat (25 and 76 cm row spacing), and 3-crop/ 2-year (25 and 76 cm row spacing).

## Materials and Methods

The experimental design for this study was a randomized complete block with four replications. The six treatments were arranged in a two row spacing by three cropping pattern factorial. The 76 cm rows represent typical row planting and the 25 cm rows simulate drill planting. The three cropping patterns were monocrop soybeans, doublecrop soybeans-wheat, and the 3-crop/ 2-year pattern involving soybeans and wheat. The six cropping systems were MC-25, MC-76, DC-25, DC-76, 3/2-25, and 3/2-76. The experiment was conducted at two locations: the Vegetable Research Station at Bixby, Oklahoma and the Eastern Research Station at Haskell, Oklahoma. The plots at the Bixby station were 36.6 m by 19.8 m and the plots at the Haskell station were 19.8 m by 8.8 m. A 10.7-m alley was not planted between each replication and a 4-m border was planted on each side of the test. A 3.1 m by 19.8 m section was harvested from each plot. The weight of each section harvested was taken, in kilograms, and converted into kilograms per hectare.

Two soybean cultivars were included in the study. A Group III soybean cultivar (9391) was selected as the early season soybean variety. Choska, a Group VI cultivar, was selected as the full season soybean variety (Edwards et al., 1995). During years one through three of this study, the wheat variety Karl was used (Sears et al., 1991). During years four through six, the wheat variety 2163 was used because Karl exhibited leaf rust susceptibility in 1994.

Each cropping system was managed according to accepted agronomic practices for the area. The monocrop systems (Table 1) included moldboard plowing the fields in March. The fields were disked in late April or early May and again in June. Herbicides

were applied and incorporated into the soil. Full season soybeans were planted in mid-June. The fields were cultivated in mid-July when needed and herbicides were sprayed, as needed, until August to control weeds. The monocrop soybeans were harvested in late October or early November. The land was fallowed until it was time to moldboard plow again for the next seasons planting.

The doublecrop systems are also presented in Table 1. A wheat grain crop was harvested in late June of year one. Herbicides were sprayed over the wheat stubble immediately after harvest. Full season soybeans were planted no-till. Herbicides were used during the summer as needed. These soybeans were harvested in November, as they became mature. The fields were disked twice and planted to wheat as soon as possible.

For the 3-crop/ 2-year (Table 2) systems, the fields were moldboard plowed in February of year one. The fields were disked in late March and herbicides were applied and incorporated into the soil. Early season soybeans were planted between April 1-10. The soybeans were cultivated and herbicides were applied as needed throughout the growing season. These soybeans were harvested in early September. The fields were disked twice immediately and planted to wheat. Wheat forage was evaluated from November 1 through March 1 of the next year. Wheat grain crops were obtained in June. Herbicides were applied and full season soybeans were planted, no-till, in the wheat stubble in late June. Herbicides were used as needed during the summer. Soybeans were harvested at maturity in November and the land fallowed for over four months. The land was moldboard plowed in December, January, or February.

Cultural practices within each cropping system were selected to produce maximum agronomic yields. All cultural practices were acceptable agronomic practices

for crop production in Oklahoma. The monocrop soybean systems produced only one soybean crop per year. The doublecrop systems produced one soybean crop and a wheat crop each year. The 3-crop/ 2-year systems produced two soybean crops (one early season and one full season), a wheat forage crop, and a wheat grain crop during each two year period. These systems also allowed more time for tillage compared to the doublecrop system.

Analyses of variance (ANOVA) test were conducted on soybean and wheat yield data for each period at each location and a combination analysis of all three periods at each location. Combination analyses were also conducted for each period at both locations and for all three periods. Least significant differences (LSD) were also determined for these data at the .05 level.

## Results and Discussion

Table 3 presents the soybean and wheat yield data for Bixby, OK. In Period 1 the 3/2-25 system was the highest yielding soybean system with 5192 kg/ha. It was not significantly different ( $LSD @ .05 = 553$ ) from the second highest yielding system (the MC-25, 5020 kg/ha). The third highest system was the 3/2-76 system (4387 kg/ha) followed by the MC-76 system. No difference was observed between these two systems. However, the MC-76 system was significantly different than each of two doublecrop systems. No significant difference could be observed between the DC-76 and DC-25 systems. The wheat yield analysis showed an  $LSD @ .05 = 643$ . No difference was observed between the highest yielding wheat system, the DC-25, and the second highest, the DC-76. They produced 3241 and 2734 kg/ha, respectively. While significant differences were observed between the DC-76 and 3/2-76 systems and between the DC-76 and 3/2-25 systems, no difference was observed between the 3/2-76 and the 3/2-25 systems. The lowest wheat producer was the 3/2-25 with 2007 kg/ha. The lower wheat yields were expected since the 3-crop/ 2-year pattern produced a wheat crop only once during a two year period. Period 2 identified the same top two producers as Period 1. With 6123 kg/ha the 3/2-25 system produced the highest soybean yield. The MC-25 system again produced the second highest yield at 5776 kg/ha. No significant difference ( $LSD @ .05 = 1136$ ) was observed between the 3/2-25 or the MC-25 systems. But each of these two was significantly different from each of the other systems. The third highest system, the DC-25 system, produced 4349 kg/ha. The MC-76, 3/2-76, and DC-76 followed. No significant difference was observed between each pair of these last four systems. In Period 2 wheat yield data was very low on the 3-crop/ 2-year pattern. Very

poor yields occurred in 1995 when the 3-crop/ 2-year pattern provided wheat to the system. There was no difference observed between the two doublecrop systems (LSD @ .05= 403). The DC-25 system produced the highest yield with 2567 kg/ha and it was significantly higher than each of the other three systems. The DC-76 system produced 2397 kg/ha and it too was significantly different then each of the other systems. The soybean yield results from Period 3 were totally different from the other two periods. With a yield of 4212 kg/ha the MC-25 system was the highest producer. With an LSD @ .05= 442, no significant difference was observed between the MC-25 and MC-76, the MC-25 and DC-25, or between the MC-25 and 3/2-25 systems. The second highest producer was the MC-76 system with 4204 kg/ha. No difference could be found between the DC-25 and 3/2-25, and between the DC-25 and 3/2-76 systems or between the 3/2-25 and 3/2-76 systems or between the 3/2-25 and DC-76 systems. In this period the 3-crop/ 2-year pattern was in the bottom half where it had been one of the top producers in the two previous periods. In wheat production, the DC-76 system was the highest yielding system with 3870 kg/ha. No significant difference was observed between the DC-76 and the next highest producer, the 3/2-25 system (LSD @ .05= 495). There was a difference observed between the 3/2-25 and the 3/2-76 systems, but no difference was observed between the 3/2-76 and the DC-25 systems. All three periods were pooled together and an LSD @ .05= 431 was determined. In the pooled soybean data the 3/2-25 system was the highest producer with a yield of 5036 kg/ha. No difference was observed between it and the second highest producer the MC-25 system (5003 kg/ha). A significant difference was found between the MC-25 and the third highest producing system (MC-76, 4121 kg/ha); however, no difference could be observed between the MC-76, the MC-



76 and 3/2-76, or the MC-76 and DC-25 systems. There was a significant difference observed between the DC-25 and the lowest producing system, the DC-76 (3460 kg/ha). In the pooled wheat data an LSD @ .05= 314 was determined. As in the three periods, the DC-76 system was the highest wheat yielding system with 3001 kg/ha. It was followed by its counterpart the DC-25 system with 2958 kg/ha. No significant difference was observed between these two systems. A significant difference was observed between the DC-25 system and 3/2-25 system and between the DC-25 and 3/2-76 system, but no difference was observed between the two 3-crop/ 2-year systems. The 3/2-76 system was the lowest yielding wheat producer with 1908 kg/ha.

Table 4 represents the soybean and wheat yield data for Haskell, OK. The results at Haskell are fairly similar to those found at Bixby. In Period 1 the 3/2-25 system was the top soybean producer with 6668 kg/ha. Followed by its counterpart the 3/2-76 with 6508.4 kg/ha. No significant difference was observed between these two systems (LSD @ .05= 445). There was a difference observed between the 3/2-76 and the third highest producing system, the DC-25 system (5966 kg/ha). No significant difference was observed between the DC-25 system and the DC-76 or between the DC-25 system and the MC-76 systems. There was a difference observed between the MC-76 and the lowest producing system the MC-25 (2825 kg/ha). In the wheat yields from Period 1 the 3/2-76 system was the highest wheat producer with 1446 kg/ha. It was followed by the 3/2-25 system with 1410 kg/ha. With an LSD @ .05= 335 no significant difference was observed between any of the four wheat yields. With a yield of 5593 kg/ha, the MC-25 system was the highest soybean producer in Period 2. It was followed by the two 3-crop/ 2-year systems; the 3/2-25 (5588 kg/ha) and the 3/2-76 (5318 kg/ha) systems,

respectively. No difference was observed between the MC-25 system and the 3/2-25 system or between the MC-25 system and the 3/2-76 system (LSD @ .05= 339). There was a significant difference observed between the 3/2-76 system and the DC-25 system. No difference was observed between the DC-25 and the DC-76 systems or between the DC-25 and the MC-76 systems. The MC-76 system was the lowest producing system at 4677 kg/ha. The same problem occurred in the wheat yield data here as in the Period 2 data at Bixby. Yields for the 3-crop/ 2-year systems were extremely poor. No significant difference was observed between the two doublecrop systems (LSD @ .05= 655). The DC-25 system was the top wheat producer with 2810 kg/ha and the DC-76 followed with 2579 kg/ha. In Period 3, no significant difference was observed between the top two soybean producers (LSD @ .05= 735). The top producer was the 3/2-25 system with 5094 kg/ha. It was followed by the 3/2-76 system with 5008 kg/ha. No significant difference was observed between the second and third highest producers, the 3/2-76 and the MC-76 systems. The MC-76 system produced 4280 kg/ha. No significant difference was observed between the MC-76 system and each of the remaining three systems. The DC-76 system was the lowest producing soybean system in Period 3 with 3749 kg/ha. In the wheat production, the DC-25 system was the top wheat producing system with 6727 kg/ha. It was significantly different than each of the other three systems (LSD @ .05= 739). The next highest producing system was the DC-76 system (4835 kg/ha). It too was significantly different from each of the remaining systems. The two 3-crop/ 2-year systems rounded out the bottom. There was no difference observed between these two systems. The 3/2-25 system was the lowest producing system at 3421 kg/ha. The data from all three periods was again pooled together. With the pooled data an LSD @

.05= 273 was determined. With this pooled data it was observed that the 3/2-25 system was the highest producing system with 5783 kg/ha of soybeans produced. Its counterpart the 3/2-76 system was the second highest producer with 5612 kg/ha produced. No significant difference was observed between these two systems. There was no significant difference observed between the DC-25 and MC-76 systems or between the DC-25 and DC-76 systems. A difference was found between the DC-76 system and the lowest soybean producing system the MC-25 (4083 kg/ha). With the pooled wheat data the DC-25 system was found to be the top producing system with 3561 kg/ha produced. It was significantly different than each of the other three systems (LSD @ .05= 327). The DC-76 system was the second highest producing system (2847 kg/ha) followed by the 3/2-76 system (1824 kg/ha) and the 3/2-25 system (1731 kg/ha). A difference was found between the DC-76 system and the 3/2-76 systems, but no difference could be found between the 3/2-76 and 3/2-25 systems.

The data from all three periods at both the Bixby and Haskell locations were pooled (Table 5). The combined Period 1 results showed no significant difference between the top three systems (LSD @ .05= 1154). The top producing system was the 3/2-25 system with 5930 kg/ha. It was followed by the 3/2-76 and MC-76 systems. No difference was observed between the 3/2-76 and MC-76 systems, 3/2-76 and DC-76 systems, or between the 3/2-76 and DC-25 systems. Also, no difference was observed between the MC-76 system and each of the remaining systems. The MC-25 system produced the lowest soybean yield with 3923 kg/ha. In the combined Period 1 wheat production, no difference was observed between any of the four systems (LSD @ .05= 823). The DC-25 system produced the most wheat at 2194 kg/ha. It was followed by the

DC-76, 3/2-76 and finally the 3/2-25 system. In the combined Period 2 the top producer again was the 3/2-25 system with 5855 kg/ha of soybeans produced. The MC-25 system followed with 5684 kg/ha. With an LSD @ .05= 733, no significant difference was observed between these top two systems. Also, no significant difference was observed between the 3/2-76, the third highest producing system, and each of the remaining three systems. In the wheat yields the DC-25 system was the top producer with 2689 kg/ha produced. The DC-76 system followed with no difference being observed between these two systems (LSD @ .05= 335). A significant difference was observed between the DC-76 system and each of the two 3-crop/ 2-year systems. The 3/2-25 system was the lowest producing wheat system. The combined Period 3 soybean data showed some interesting results. With an LSD @ .05= 599 no significant difference was observed between any of the six systems. The 3/2-25 system was the top soybean producer with 4443 kg/ha of soybeans produced. The 3/2-76 system followed with 4303 kg/ha. Then came the MC-76, MC-25, DC-76 and DC-25 systems, respectively. The DC-25 system was the lowest producing system with 3853 kg/ha. Again the doublecrop systems out produced the 3-crop/ 2-year systems in wheat production. The DC-25 system produced 4897 kg/ha making it the top wheat producer. The DC-76 system came next with 4353 kg/ha. No significant difference was observed between these two systems (LSD @ .05= 1116). In the 3-crop/ 2-year systems the 3/2-25 out produced the 3/2-76 system 3607 to 3461 kg/ha. No difference was observed between the DC-76 and each of the two 3-crop/ 2-year systems. With all three periods combined and both locations combined the 3/2-25 system was the top soybean producer with 5410 kg/ha of soybeans produced. It was significantly different from each of the remaining five systems. The 3/2-76 system was

the next highest producer with 4780 kg/ha produced. It was followed by the MC-25, MC-76, DC-25, and DC-76 systems, respectively. The DC-76 system produced the least amount of soybeans at 4241 kg/ha. No difference was observed between these last five systems. In the final wheat data no difference could be found between the top two systems (LSD @ .05= 865). The DC-25 system was the number one wheat producing system with 3260 kg/ha of wheat produced. Its counterpart the DC-76 system followed with 2924 kg/ha produced. Rounding out the bottom were the 3/2-25 system (1893 kg/ha) and the 3/2-76 system (1866 kg/ha). In a few instances the monocrop pattern produced the highest soybean yields, but normally the 3-crop/ 2-year pattern produced the highest soybeans yields. On the other hand, the wheat production followed what was expected in yields. The doublecrop pattern (two wheat crops) out-performed the 3-crop/ 2-year pattern (one wheat crop). In all cases the doublecrop pattern produced the highest yielding wheat system.

## Conclusion

The 3-crop/ 2-year pattern was the highest soybean producing pattern. The 3-crop/ 2-year pattern produced 5410 kg/ha of soybeans in 25 cm rows and 4780 kg/ha of soybeans in 76 cm rows. This system was the second best soybean producing system at Bixby and it was the best producing system at Haskell over the three periods. At Bixby the monocrop pattern was the more productive soybean producing pattern (MC-25= 5003 kg/ha and MC-76= 4121 kg/ha) compared to the doublecrop pattern (DC-25= 3904 kg/ha and DC-76= 3460 kg/ha). At Haskell these two patterns switched with the doublecrop pattern out-yielding the monocrop pattern. Looking at the overall data the monocrop pattern out-performed the doublecrop pattern in soybean yields. Overall the MC-25 system produced 4543 kg/ha and the MC-76 system produced 4502 kg/ha.

In wheat production the doublecrop pattern was by far the better wheat producing pattern. When looking at the combined data the DC-25 system produced 3260 kg/ha of wheat and the DC-76 system produced 2924 kg/ha. The 3-crop/ 2-year pattern was consistent though with the 3/2-25 system producing 1893 kg/ha of wheat and the 3/2-76 system producing 1866 kg/ha. At Bixby and Haskell both doublecrop systems out-performed the two 3-crop/ 2-year systems.

The yield results from this study provide support for the use of the 3-crop/ 2-year pattern over the other two cropping patterns with the 3/2-25 system being the most productive. In the soybean yields the 3/2-25 system was the highest producing system two of the three periods at Bixby (Period 1= 5192 kg/ha and Period 2= 6123 kg/ha). In Period 3 it was the fourth highest producing system (3793 kg/ha). At Haskell it was again the highest producing soybean system in two of the three periods (Period 1= 6668

kg/ha and Period 3= 5094 kg/ha) and it was the second highest producing system in Period 2 with 5588 kg/ha produced. Overall the 3/2-25 system produced 5410 kg/ha of soybeans and 1893 kg/ha of wheat. The next most consistent producing system was the 3/2-76 system. In the three periods it was in the top two or three in soybean production at both Bixby and Haskell. Even though it was one of the lowest wheat producing systems, the 3/2-76 is still the second best system in this study.

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TABLE 1  
MONTHLY ACTIVITIES FOR THE MONOCROP AND  
DOUBLECROP SYSTEMS

	Monocrop	Doublecrop
January		
February		Topdress wheat with nitrogen <sup>†</sup>
March	Moldboard plow.	
April	Disk in the later part of the month.	
May	Disk if needed.	
June	Disk around the middle of the month. Apply preplant herbicides, incorporate, and plant soybeans.	Harvest wheat, spray for weed control and plant soybeans, no-till.
July	Cultivate soybeans or use herbicides for weed control.	Control weeds with herbicides.
August	Control the weeds by spot spraying if necessary	Control weeds with herbicides.
September		
October	Harvest soybeans in later part of month.	
November		Harvest soybeans and double disk land after harvest. Plant winter wheat. Fertilizer applied
December	Fallow until time to moldboard plow for next year.	

<sup>†</sup> Wheat was established in November of the year before.

TABLE 2  
MONTHLY ACTIVITIES FOR THE 3-CROP/ 2-YEAR SYSTEMS

	Year 1	Year 2
January	Moldboard plow as early as possible (Dec., Jan., or Feb.).	
February		Topdress wheat with nitrogen
March	Double disk in the later part of the month.	
April	Apply preplant herbicides, incorporate and plant early season soybeans as early as possible.	
May	Cultivate and use herbicides as needed.	
June	Cultivate and use herbicides, if necessary.	Harvest wheat grain; spray wheat stubble for weed control, and plant (no-till) full season soybeans.
July	Control the weeds by spot spraying.	Use herbicides, if necessary.
August		Use herbicides, if necessary.
September	Harvest the soybeans and double disk and plant wheat. Fertilizer applied	
October		
November	Wheat forage produced from November 1 through March 1	Harvest soybeans at maturity. Fallow period
December		Moldboard plow or use other tillage as early as possible (Dec., Jan., or Feb.).

TABLE 3  
YIELDS FROM SIX CROPPING SYSTEMS INVOLVING  
SOYBEANS AND WHEAT AT BIXBY, OK: 1992-97

Management Systems	Period 1 1992-93	Period 2 1994-95	Period 3 1996-97	Average of 3 periods
	Kg/ ha/ Period			
	Soybeans			
MC-25	5020	5776	4212	5003
MC-76	4237	3921	4204	4121
DC-25	3406	4349	3956	3904
DC-76	3480	3399	3500	3460
3/2-25	5192	6123	3793	5036
3/2- 76	4387	3862	3598	3949
LSD @ .05	553	1135	442	431
	Wheat			
DC-25	3241	2567	3066	2958
DC-76	2734	2397	3870	3000
3/2-25 <sup>†</sup>	2007	362	3793	2054
3/2-76 <sup>†</sup>	2067	380	3276	1908
LSD @ .05	643	403	495	314

<sup>†</sup> A wheat grain crop was harvested only once per period for the 3-crop/ 2-year pattern.

TABLE 4

YIELDS FROM SIX CROPPING SYSTEMS INVOLVING  
SOYBEANS AND WHEAT AT HASKELL, OK: 1992-97

Management Systems	Period 1 1992-93	Period 2 1994-95	Period 3 1996-97	Average of 3 periods
Kg/ ha/ Period				
Soybeans				
MC-25	2825	5593	3830	4083
MC-76	5692	4677	4280	4883
DC-25	5966	4879	4224	5023
DC-76	5771	4748	3749	4756
3/2-25	6668	5588	5094	5783
3/2- 76	6508	5318	5008	5612
LSD @ .05	445	339	735	273
Wheat				
DC-25	1147	2810	6727	3561
DC-76	1126	2579	4835	2847
3/2-25 <sup>†</sup>	1410	362	3421	1731
3/2-76 <sup>†</sup>	1446	380	3647	1824
LSD @ .05	335	655	739	327

<sup>†</sup> A wheat grain crop was harvested only once per period for the 3-crop/ 2-year pattern

TABLE 5

AVERAGE YIELDS FOR CROPPING SYSTEMS INVOLVING SOYBEANS AND  
WHEAT AT BIXBY AND HASKELL, OK COMBINED: 1992-97

Management Systems	Period 1 1992-93	Period 2 1994-95	Period 3 1996-97	Average of 3 periods
Kg/ ha/ Period				
Soybeans				
MC-25	3923	5684	4021	4543
MC-76	4965	4299	4242	4502
DC-25	4588	4548	3853	4330
DC-76	4723	4139	3862	4241
3/2-25	5930	5855	4444	5410
3/2- 76	5448	4590	4303	4780
LSD @ .05	1154	733	599	560
Wheat				
DC-25	2194	2689	4897	3260
DC-76	1930	2488	4353	2924
3/2-25 <sup>†</sup>	1709	362	3607	1893
3/2-76 <sup>†</sup>	1757	380	3461	1866
LSD @ .05	823	335	1116	865

<sup>†</sup> A wheat grain crop was harvested only once per period for the 3-crop/ 2-year pattern.

## APPENDICES



# APPENDIX I

## SELECTED INPUT COST FOR CROPPING SYSTEMS

Input	Cost <sup>†</sup>	Source
Seed:		
Choska	\$.70/ kg	Oklahoma Foundation Seed
9391	\$.79/ kg	Ron Limon
2163	\$.66/ kg	Ron Limon
Chemicals:		
Roundup	\$12.87/ L	Estes Chemical Co.
Lasso	\$6.79/ L	Estes Chemical Co.
Sencor	\$2.45/ L	Estes Chemical Co.
Poast Plus	\$13.14/ L	Estes Chemical Co.
Fertilizer:		
18-46-60	\$.29/ kg	Muskogee Farmers Assoc.
6-24-24	\$.32/ kg	Muskogee Farmers Assoc.
46-0-0	\$.22/ kg	Muskogee Farmers Assoc.
Custom Rates for		
Machinery:		
Planting	\$14.81/ ha	Oklahoma Farm and Ranch
Fertilizing	\$2.47/ ha	Custom Rates, 1994-1995
Spraying	\$4.94/ ha	Oklahoma Farm and Ranch
Disking	\$12.35/ ha	Custom Rates, 1994-1995

<sup>†</sup> All cost were determined on August 14, 1998

## APPENDIX II

### CALENDAR OF ACTIVITIES 1992-1997

1992

January (B) <sup>†</sup> 30 <sup>‡</sup> -Top dressed wheat w/ 80 lb. N/ A	July (H) Planted full season soybeans
February	August (H) 25-Harvested early season soybeans 28-Planted 90 lb. wheat/ A (B) 24-Harvested early season soybeans 31-Disked twice and planted 90 lb. wheat/ A on 3-crop/ 2-year treatments
March	September
April (H) 8-Planted early season soybeans (B) 9-Disked twice, planted early season soybeans, and sprayed 4 oz. Pursuit	October
May	November (H) 17-Harvested full season soybeans, disked twice and planted 90 lb. wheat/ A (B) 17-Harvested full season soybeans, planted 90 lb. wheat/ A, and applied 80 lb. N/ A
June (B) 26-Harvested wheat plots, disked once, applied 1 qt. Treflan, ¼ lb. Sencor and 4 oz. Pursuit on tilled plots, planted full season soybeans 27-Sprayed 1 qt. Roundup, 3 qt. Lasso and ¼ lb. Sencor/ A on no-till plots, planted no-till full season soybeans	December

<sup>†</sup> (H) -Haskell Research Station (B)-Bixby Research Station

<sup>‡</sup> Date activity was performed

# APPENDIX II (CONTINUED)

1993

January	July
February (H) 2-Top dressed 80 lb. N/ A to wheat plots	August (B) 27-Planted 90 lb. wheat/ A, fertilized, applied 80 lb. N/ A
March	September
April	October
May	November (B) 9-Harvested full season soybeans
June (B) 22- Harvested wheat, disked twice, applied herbicides, planted full season soybeans (H) 23- Harvested wheat	December

# APPENDIX II (CONTINUED)

1994

January	July
February (H) 15- Top dressed wheat with 80 lb. N/ A (B) 16- Top dressed wheat with 80 lb. N/ A	August
March	September (B) 14- Harvest early season soybeans, planted 90 lb. wheat/ A and applied 40 lb. N/ A (H) 9- Harvested early season soybeans, planted 90 lb. wheat/ A and applied 40 lb. N/ A
April (H) 8- Sprayed early season plots with 2.8 pt. Scepter, 2.8 pt. Prowl. 9- Planted early season soybeans (B) 1- Planted early season soybeans, fertilized	October (H) 26- Harvested full season soybeans
May (H) 19- Cultivated early season soybeans (B) 19- Cultivated early season soybeans	November
June (B) 1- Fertilized with 250 lb. 6-24-24, sprayed 1 pt Dual, 3 oz. Pursuit, incorporated. 15- Planted full season soybeans (H) 17- Harvested wheat, sprayed 3 qt. Lasso, 1qt. Roundup, ¼ lb. Sencor. 22- Planted doublecrop soybeans	December

# APPENDIX II (CONTINUED)

1995

January	July
February	August
March	September
April	October (H) 30- Harvested full season soybeans, disked all plots three times, and sprayed 1 ½ pt. Poast, 2 lb. Ammonia sulfate. 31- Planted 90 lb. wheat/ A
May	November (B) 3- Harvested full season soybeans. 8- Disked three times planted 90 lb. wheat/ A
June	December

# APPENDIX II (CONTINUED)

1996

January	July (H) 3- Cultivated 30" rows. 7- Cultivated. 21- Spot sprayed with Poast Plus, by hand (B) 8- Cultivated 30" rows 10- Replanted 10 and 30" no-till soybeans. 17- Cultivated 30" clean till soybeans
February (B) 13- Top dressed wheat with 80 lb. N/ A (H) 13- Top dressed wheat with 80 lb. N/ A	August (B) 2- Sprayed 2,4-DB and Basagran on no-till plots. 7- Cultivated 30" rows. 30- Harvested early season soybeans (H) 23- Harvested early season soybeans
March (B) 22- Limed and disked plots (H) 19- Sprayed 2 pt. Hoelon. 22- Fertilized all plots with 18-46-60	September
April (H) Planted early season soybeans, sprayed with 2/3 pt. Prowl and 2/3 pt. Scepter, incorporated. (B) 5- Planted early season soybeans, applied 2/3 pt. Prowl and 2/3 pt. Scepter, incorporated	October
May (B) 20- Cultivated 30" rows. 22- Sprayed 10" rows with Poast Plus and crop oil. (H) Cultivated 30" rows.	November (B) 11- Harvested full season soybeans.
June (B) 14- Planted clean till 30" full season soybeans, sprayed with 1 1/2 pt. Treflan and 2.8 oz. Scepter, incorporated. 17- Cultivated 30" rows, harvested wheat, planted no-till plots, sprayed with 2 1/2 qt. Lasso, 1 qt. Roundup, 2.8 oz. Scepter O.T., planted 10" no-till plots 18- Planted 10" clean-till plots. 30- Sprayed 2 pt. Blazer on no-till and clean-till plots (H) 12- Harvested wheat. 13- Planted full season soybeans, sprayed doublecrop no-till with 2 1/2 qt. Lasso, 1 qt. Roundup, and 2.8 oz. Scepter, sprayed clean-till monocrop soybeans with 1 1/2 pt. Treflan and 2.8 oz. Scepter.	December

# APPENDIX II (CONTINUED)

1997

January	July (H) 30- Thinned out 10' section in 10" plots (B) 2- Sprayed 1 ½ pt. Treflan and .32 oz. Authority on clean-till plots, harvested wheat plots, planted no-till and clean-till plots. 3- Sprayed no-till plots with 1 ½ qt. Roundup, 2 ½ qt. Lasso, 0.8 pt. 2,4-DB, 2.8 oz. Scepter. 30- Thinned out 10' section of 10" plots
February (B) 11- Top dressed 40 lbs. N/ A on wheat plots (H) 5- Top dressed 40 lbs. N/ A on wheat plots	August (B) 26- Sprayed 2 pt. Poast Plus and crop oil on 30" no-till plots
March	September
April (B) 3- Applied Harmony Extra to late planted wheat plots	October
May	November (H) 5- Harvested full season soybeans, chiseled twice, disked twice, planted 90 lb. wheat/ A on plots #3 and #6 (B) 23- Harvested full season soybeans, disked once, planted 100 lb. wheat/ A, and applied 40 lb. N/ A
June (H) 3- Applied ¼ oz. Sencor and 1 lb. Treflan to 10" and 30" monocrop plots. 19- Harvested wheat plots, planted 10" doublecrop plots, sprayed edges with Treflan 20- Planted 30" double and monocrop plots. 21- sprayed no-till plots with 2 ½ qt. Lasso, 1 ½ qt. Roundup, and 2.8 oz. Scepter.	December

## VITA<sup>2</sup>

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